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Supplementary Information

for

THE ARCTIC GAS PIPELINE

J.A. Harvie, Vice-President, Engineering and Operations

Canadian Arctic Gas Pipeline Limited

There have been several developments subsequent to the submission of this paper six months ago. On March 21, 1974, Canadian Arctic Gas Pipeline Limited and Alaskan Arctic Gas Pipeline Company submitted to the governments of Canada and the United States respectively the applications and some supporting exhibits and reports for permission to build and operate the proposed international pipeline system. The exhibits concerned such important considerations as socio-economic impacts in northern Canada and Alaska; environmental effects; the proposed pipeline route; engineering, design, construction and operation of the system; and alternative routes and modes of transporting the northern gas, which were found to be less desirable than the gas pipeline proposed.

Since that time, some preliminary hearings concerning the application have been held in Canada and it is hoped that some of the formal hearings will begin this Fall. In addition to the Arctic Gas application hearings, Canada's National Energy Board will begin hearings next month concerning Canada's total supply and demand for natural gas, particular reference being given to the country's procedures for determining any exportable surplus. The outcome of these proceedings will, therefore, be important to the ultimate determination of what quantities of Canadian natural gas may be transported to United States markets via the Arctic Gas system.

Also this Fall, Alaskan Arctic Gas and Canadian Arctic Gas plan to submit further supporting exhibits to regulatory authorities in the United States and Canada, respectively. These submissions will include exhibits on costs, tariffs, gas supply and markets, financing, anticipated impacts on

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the national economies of both countries and other factors. It is hoped that the federal government hearings in both countries will get underway promptly, so that government approvals can be achieved on a schedule which will allow this project to help meet the energy needs of both Canada and the United States on as timely a basis as possible.

Thank you, Mr. Chairman.

August 23, 1974.

THE ARCTIC GAS PIPELINE

J. A. Harvie, Vice-President, Engineering and Operations

Canadian Arctic Gas Pipeline Limited

Self-sufficiency in energy supplies by 1980 has been stated as national policy objectives of the highest priority by the governments of both Canada and the United States.

A vital consideration in the attainment of these objectives involves the degree of co-operation in energy development by the two nations which share the major portion of North America.

Each nation will undoubtedly, continue to place first priority on assurance of its own energy needs. Is it therefore appropriate that Canada and the United States emphasize "all-Canadian" and "all-American" energy policies in order to maximize assurance of energy supplies? Or can these national objectives of energy self-sufficiency and security of supply be achieved, to some extent, by co-operation between the two nations?

The question is an important factor in the Arctic Gas proposal for a major pipeline to transport both Canadian and U.S. natural gas from the western Arctic to both Canadian and American consumers.

It is the view of Arctic Gas that co-operation, in many instances, can contribute substantially to the attainment of the energy self-sufficiency and security objectives of each nation, while also contributing to their economic objectives.

It is beyond the scope of this paper to explore the entire range of Canadian and American energy relationships. This paper will, however, show how the proposed Arctic Gas system can best serve the national energy objectives of both Canada and the United States.

Need for Energy Security

Recent trends in the growth of energy demand and development of indigenous supplies, combined with interruptions of imports from Arab oil producing nations, have heightened public awareness of the importance of adequate and assured supplies of energy.

In the United States, the supply of proved remaining reserves of crude oil and natural gas (accounting for some 80 percent of total energy demand) has been steadily declining, while demand has continued to grow. The resultant increase in the portion of energy demand supplied by imported crude oil has created a vulnerability to overseas supply disruptions.

In respect of natural gas, proved and recoverable reserves in the contiguous 48 states (and therefore accessible to pipeline transmission) declined between 1967 and 1973 by nearly 19 percent, from about 8.21×10^{12} cubic meters (290 trillion cubic feet) to 6.62×10^{12} cubic meters (234 trillion cubic feet). During the same period, the annual rate of consumption increased by 16.7 percent. Unmet demand through refusal of new customers and curtailment of established customers -- mainly industrial users -- represents a substantial additional short-fall in existing supplies.

The situation in Canada has been somewhat different. Primarily because of oil and gas production from its four western provinces, Canada during recent years has been the only industrialized nation in the western world which has produced as much energy as it consumes.

This, however, has not shielded Canada from disruptions in the supplies of overseas crude oil. All of Canada's petroleum requirements east of Ontario are provided by imports, which are more than offset by exports to the United States. The pipeline system which transports western Canada oil is now to be extended farther east to supply refineries in Quebec, thereby minimizing vulnerability to disruptions of overseas imports.

But aside from extending its transportation system, Canada must soon also start exploiting new sources of oil and natural gas to supplement production from western Canada, if it is to maintain a position of energy self-sufficiency. Production of both conventional crude oil and natural gas in western Canada is expected to start declining by the end of this decade, by which time the rate of oil production will be less than anticipated Canadian demand, while natural gas production will be inadequate to meet Canadian demand plus volumes already authorized for export to U.S. markets.

Canada, however, does not appear to have any shortage of potential fossil fuel resources. Including conventional crude oil, natural gas, huge tar sands deposits such as at Athabasca, as well as coal, Canada's total potential resources of fossil fuels amount to the equivalent of more than 159×10^9 cubic meters of crude oil (one trillion

barrels, based on the most recent estimates by the Geological Survey of Canada, which we have converted into equivalent barrels of oil on the basis that six million cubic feet of gas are equal to one barrel of crude, and four barrels of crude oil are equal to one ton of coal).

This potential resource base of 159×10^9 cubic meters (one trillion barrels) of oil equivalent amounts to more than three times the projected Canadian demand for fossil fuels during the 80-year period from 1970 to 2050, as estimated by the federal government's Department of Energy, Mines and Resources.

While the four western provinces now provide virtually all of Canada's natural gas production, they account for only about 15 percent of the nation's potential gas resources. Again quoting from the latest study of the Geological Survey of Canada available at time of writing, the remaining discovered plus potential natural gas resources of the western provinces are estimated at less than 2.83×10^{12} cubic meters (100 trillion cubic feet), compared with nearly 19.82×10^{12} cubic meters (700 trillion cubic feet) for the Arctic and offshore areas.

Current demand for Canadian natural gas exceeds 198.2×10^6 cubic meters (seven billion cubic feet) per day, including more than 113.26×10^6 cubic meters (four billion cubic feet) per day for domestic use and 84.95×10^6 cubic meters (three billion cubic feet) per day committed to exports to the United States under contracts authorized by the Government of Canada. Only if new supply sources are available to supplement production from the western provinces will Canada be able to provide all of its own natural gas requirements and also fulfill its existing export commitments beyond the end of this decade.

Alternative Approaches for Northern Gas Supplies

The large proven and potential reserves in the northwestern Arctic can make an important contribution toward meeting these urgent natural gas requirements of both Canada and the United States.

On the North Slope of Alaska, the proved reserves at Prudhoe Bay have been estimated by the American Gas Association at 736.23×10^9 cubic meters (26 trillion cubic feet) -- 10 percent of the total U.S. proved remaining supply. Ultimate potential natural gas reserves on the North Slope are expected to be in the order of 8.49×10^{12} cubic meters (300 trillion cubic feet).

In Canada, potential reserves in the Yukon and Northwest Territories -- excluding the Arctic Islands -- have been estimated by the Geological Survey of Canada at some 2.83×10^{12} cubic meters (100 trillion cubic feet)

-- more than the remaining discovered plus potential reserves of western Canada. Exploration activity during the past few years has proven up substantial natural gas reserves in the Mackenzie River Delta region of this area, some 643.7 kilometers (400 miles) east of Prudhoe Bay.

A single transportation system to handle natural gas from both the North Slope of Alaska and the Mackenzie Delta region would afford significant economic benefits. It would involve a large diameter pipeline across Canada to connect with existing and with new transmission systems to serve both U.S. and Canadian consumers in market regions virtually from coast-to-coast.

The alternative is an "all-American" system to transport Alaskan gas to U.S. consumers, and an "all-Canadian" system to transport Mackenzie Delta gas to Canadian consumers. This alternative, in the opinion of Arctic Gas, has clearly fewer advantages for either nation.

The "all-American" system would involve a large diameter pipeline stretching some 1448.4 kilometers (900 miles) from Prudhoe Bay across Alaska to the Pacific coast, where the gas would be liquefied for shipment by tanker to U.S. westcoast ports.

It is the contention of Arctic Gas that this alternative suffers from the following disadvantages:

- Cost of transportation, as compared with the overland pipeline route, is significantly higher.

- A smaller amount of natural gas would ultimately be delivered to U.S. consumers. This "all-American" transportation system would consume more fuel, primarily in the process of liquefaction, and it offers no prospect of transporting any gas from northern Canada to U.S. consumers.

- Tanker deliveries of LNG would serve only U.S. consumers on the west coast seaboard conveniently, while the need of U.S. consumers east of the Rockies for additional natural gas supplies is at least equally as urgent.

- Transportation of LNG by ocean tankers does not provide as great a degree of reliability of service as pipeline transportation of natural gas, with its much longer history of operation throughout North America.

(Detailed results of studies upon which these conclusions were based were being prepared at time of writing by Arctic Gas for submission to Canadian and U.S. regulatory agencies, in support of applications to construct the proposed Arctic Gas pipeline.)

Similarly, an "all-Canadian" pipeline to transport natural gas from the Mackenzie Delta to Canadian consumers also presents significant problems. The major difficulty here would be to secure the volume of throughput required to attain economic viability for such a pipeline system.

At any given point in time, two factors would determine the throughput volume of an "all-Canadian" natural gas pipeline from the Mackenzie Delta. The factors are the amount of available supply from proven reserves, and the amount of market demand in Canada unsatisfied by production from the four western provinces.

The delivery capacity of the 1200 millimeter (48-inch) diameter pipeline proposed by Arctic Gas, at full compressor horsepower, is in excess of 113.26×10^6 cubic meters (four billion cubic feet) per day. This is greater than the total average daily Canadian demand for natural gas in 1973.

In the view of Arctic Gas, there seems, at this time, to be little prospect for either sufficient supply or market demand in Canada to build an all-Canadian natural gas pipeline, which is economic for consumers, until well beyond the point in time that additional supplies will be required to supplement production from the western provinces. And without the availability of such supplementary supplies by 1980, Canada would either have to endure an increasing shortage of natural gas, or else reduce deliveries of contracted exports to the United States in order to meet its own needs. Both solutions are against the interests of Canada, and the latter would hurt the United States too. Neither result should be accepted when the workable alternative is so clearly available.

The Arctic Gas System

The proposed Arctic Gas pipeline system is an appropriate example of co-operative Canadian-American energy development for several reasons:

- It would provide a significant contribution to the energy supplies of both Canadian and American consumers.
- It would provide important and well-defined economic benefits arising from such co-operative development.
- It is the largest single energy project ever proposed and the largest project of any kind ever proposed by the private sector.
- It involves the natural resources and the financial resources of both nations.

Including new and expanded connecting pipeline facilities serving Canadian and U.S. consumers, the Arctic Gas project represents the major segment of a proposed undertaking requiring a capital investment in excess of $8,000,000,000. Of this, about $600,000,000 would be required for new facilities constructed across northern Alaska by Alaskan Arctic Gas Pipeline Company; approximately $5,000,000,000 for Canadian Arctic Gas Pipeline Limited facilities across Canada; and the remainder for connecting pipeline systems.

Not including connecting pipelines, the Arctic Gas system will embrace some 4184.3 kilometers (2,600 miles) of pipeline, including more than 3057.7 kilometers (1,900 miles) of 1200 millimeter (48-inch) diameter pipe, and some 1086.3 kilometers (675 miles) of 1050 millimeter (42-inch) pipe.

By segments, the overall project in Alaska and Canada is delineated approximately as follows:

- from Prudhoe Bay to the Alaska-Canada border, 313.8 kilometers (195 miles);
- from the border to a junction with a similar line from the Mackenzie Delta, 474.7 kilometers (295 miles);
- from the Mackenzie Delta to the point of junction with the line from Alaska, 233 kilometers (145 miles);
- a common facility from the above junction to a dividing point in the vicinity of Calgary, Alberta, 2092.1 kilometers (1300 miles);
- separate legs to delivery points on the British Columbia-Idaho and Saskatchewan-Montana borders, of 450.6 kilometers (280 miles) and 635.7 kilometers (395 miles), respectively (1050 millimeter diameter pipe).

Three principal delivery points for the Arctic Gas pipeline are:

1) At Kingsgate on the British Columbia-Idaho boundary, connecting with facilities to both northern and southern California markets.

2) At Empress on the Alberta-Saskatchewan border, connecting with the existing TransCanada PipeLines system for delivery to markets in eastern Canada, namely Ontario and Quebec.

3) At Monchy on the Saskatchewan-Montana border, connecting with the proposed $1,300,000,000, 2735.9 kilometer (1700 mile) pipeline of Northern Border Pipeline system, which would extend across the U.S. midwest and into Pennyslvania.

4) There will be interconnections with existing pipelines in Alberta.

The pipeline will be fully buried. Estimated land requirements throughout Canada and Alaska for right-of-way and permanent facilities will total about 207.2 square kilometers (80 square miles).

Specifications for the 1200 millimeter (48-inch) pipe call for X70 API steel, with a wall-thickness of approximately 19 millimeters (three-quarters of an inch). Maximum allowable operating pressure will be 11,583.2 kiloNewtons per square meter (1,680 pounds per square inch).

Installed compressor station and propane refrigeration station horsepower at full capacity will include some 1,215,490 kilowatts (1,630,000 horsepower) for gas compression, and 202,830 kilowatts (272,000 horsepower) for refrigeration compression.

Throughout areas of permafrost, approximately north of 60° latitude the gas will be chilled at each compressor station to temperatures below 0° C (32° F). In other areas, the gas will be chilled at each compressor station to avoid a cascading effect of elevating temperatures.

At full compressor horespower, design capacity will be 127.42 x 10^6 cubic meters (4.5 billion cubic feet) per day of feed gas, of which 8.49 x 10^6 cubic meters (0.3 billion cubic feet) per day will be used to power the system. The resultant delivery capacity is in the order of seven percent of combined Canadian-U.S. natural gas supplies during 1973. Additional capacity could be achieved, in step with development of additional gas reserves, by means of incremental pipeline looping and additional compression power.

Following receipt of regulatory approvals, a minimum of three years would be required for assembly of materials and construction. Ditching and the laying of pipe in the north would be limited to a winter season of about four months. Construction equipment would move over temporary winter roads of compacted snow and ice to protect the vegetative mat which insulates the permafrost.

Arctic Gas History

Preliminary feasibility studies of a pipeline to transport natural gas from the southern area of the Yukon and Northwest Territories were started in 1967 by three companies, one Canadian and two U.S. Following the discovery of reserves at Prudhoe Bay in 1968, the area of interest was extended to include the Alaskan North Slope and Mackenzie Delta. Additional firms have subsequently joined the group. At the time of writing, there were 27 participating companies in Arctic Gas -- 16 Canadian and 11 U.S. -- representing a major segment of the petroleum and natural gas industries of North America.

By the end of 1973, close to $50,000,000 had been spent by Arctic Gas on detailed studies of the engineering, economic and environmental aspects of the proposed pipeline. One of the most wide-ranging study programs ever conducted by private industry, the Arctic Gas research has embraced aspects as diverse as metallurgy, soils-mechanics, thermodynamics, economics, wildlife biology, and sociology, to mention only a few.

A principal area of study has involved the concept of a fully-buried chilled natural gas pipeline. Throughout the areas of permafrost, the gas would be chilled to a temperature of about -3.9°C (25° F), so that it would be close to the soil temperature, and well below freezing. This approach

will allow the pipeline to be fully buried along the entire length, and avoid the risk of any permanent damage to high ice-content permafrost. The surface over the buried pipeline would be revegetated to re-establish a thermal insulation for the permafrost, and to arrest alluvial erosion. There would be a levelled, narrow clearing through the brush of the taiga, which would afford no impediment to wildlife movement, nor to surface water drainage.

To test the chilled gas concept, pipeline test facilities were established at Sans Sault and Norman Wells, both in the Northwest Territories, and at Prudhoe Bay, Alaska. Chilled and compressed air, used to simulate the flow of natural gas, has been circulated through 1524 meters (5,000 feet) of 1200 millimeter (48-inch) diameter test pipes at these three centres. In operation for nearly two years, the test facilities have fully validated the chilled gas concept. They have provided extensive information on stability of gas pipelines in permafrost under various simulated operating conditions; stability of different types of foundations for above-ground structures; effects of a pipeline on various forms of surface cover; drainage problems associated with Arctic pipeline construction; and construction methods, design techniques, material and equipment for use in an ultimate pipeline system.

Environmental studies, including the construction and operation of test facilities, had cost almost $20,000,000 by 1974. These studies include both wildlife and vegetation research in northern Canada and Alaska. The wildlife studies have defined possible areas where construction and operation of the pipeline could conceivably conflict with the wildlife resources, and means to avoid or minimize such conflict have been developed. The vegetation studies have shown how to restore a vegetative cover over a buried pipeline in order to prevent thermal erosion of the underlying permafrost in the vicinity of the pipeline, and to arrest alluvial erosion.

Base line studies, completed to the end of 1972, provided an immense amount of valuable information on the habitat, populations and characteristics of wildlife resources through a large segment of the north. This information was required to forecast the type, extent and duration of environmental change which will result from the construction and operation of the pipeline, and to devise means to minimize adverse change.

Subsequent environmental studies have focused on specific impact areas. They show, for example, such factors as the timing and location required for river crossings to avoid disturbance of fish; other critical periods and locations where construction activity may have to be restricted to avoid disturbance to caribou when they are calving, or migratory birds during their brief pre-migration feeding period on the Arctic coastal plain.

Some of the other study areas researched by Arctic Gas include:

1) Transportation alternatives, to provide an assessment of the engineering, economic and environmental factors involved in alternate modes and routes for transporting natural gas from the North Slope and Mackenzie Delta.

2) Economic studies, to assess the national and regional impacts of financing and operation of the pipeline on the Canadian and U.S. economies, including such aspects as employment, balance of payments, foreign exchange rates, interest rates, and cost of goods and services.

3) Financing studies. The objective has been a viable plan of financing, which would provide first priorty to Canadian investors and achieve more than 51 percent Canadian ownership of the Canadian section of the Arctic Gas Pipeline system.

4) Regional socio-economic impact of the pipeline in the Northwest Territories, Yukon and Alaska.

5) Recruitment, training and employment of northern residents, particularly native people, for the construction and operation of the pipeline.

Applications for authority to construct and operate the proposed pipeline have been made to regulatory authorities in both Canada and the United States. In Canada, the principal applications are to the National Energy Board, for a certificate of public convenience and necessity; and to the Department of Indian Affairs and Northern Development to obtain the use of federal lands for a right-of-way across the Yukon and Northwest Territories. In the United States, similar applications have been made to the Federal Power Commission and to the Department of the Interior, as well as to the State of Alaska. Extensive public hearings on these applications will be held during 1974. Hopefully, approvals will be obtained in early 1975. By the time that final approvals can be anticipated, some eight years and some $70,000,000 will have been spent on the Arctic Gas project.

In the final analysis it will be the governments of both Canada and the United States that will determine the public interest in each nation as it relates to the transportation and use of the large reserves of natural gas in the western Arctic. But it is the stated belief of Arctic Gas that Canadian and U.S. public interests will best be served by co-operative energy policies and development which recognize the mutual interests of both nations.

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SUMMARY

The proposed $5,600,000,000 Arctic Gas pipeline to transport natural gas from the North Slope of Alaska and Mackenzie Delta region of northern Canada will be the world's largest natural gas transmission pipeline. Some 4184.3 kilometers (2,600 miles) in length, the 1200 millimeter (48-inch) diameter system will have a design operating pressure of 11,583.2 kiloNewtons per square meter (1680 pounds per square inch), which will enable it to deliver in excess of 113.26×10^6 cubic meters (four billion cubic feet) of gas per day. It will be the first large natural gas pipeline in North America to traverse an extended distance across northern permafrost terrain. To maintain the integrity of high ice-content permafrost, the gas will be chilled at each compressor station to temperatures below 0° C (32° F).

A $50,000,000 program of feasibility studies and engineering design has developed answers to the particular considerations involved in this project. Included in the study program are three pipeline test facilities which have validated the chilled-gas pipeline concept, extensive environmental impact studies, and construction techniques to cope with winter Arctic climate conditions.

SOMMAIRE

Le pipe-line de $5,600,000,000 proposé par Arctic Gas pour transporter le gaz naturel de la côte nord de l'Alaska et la région du delta du Mackensie au nord du Canada sera le gazoduc le plus important du monde. D'une longueur de quelque 4184.3 kilomètres, le tuyau d'une section de 1200 mm sera conçu pour fonctionner à une pression de 11,583.2 kilonewtons par mètre carré, ce qui lui permettra de fournir plus de 113.26 x 10^6 m^3 de gaz par jour. Ce sera le premier grand pipe-line de gaz naturel d'Amérique du Nord à traverser sur une grande distance les régions nordiques de pergélisol. Afin de ne causer aucune dégradation du pergélisol, le gaz sera refroidi à chaque station de compression à des températures au-dessous de 0°C.

Un programme de $50,000,000 d'études de praticabilité et de conception technique a trouvé des solutions aux problèmes particuliers posés par ce projet. Ce programme d'études comprenait trois installations d'essais du gazoduc qui ont servi à prouver la validité d'un pipe-line à gaz refroidi, une étude complète de l'impact sur l'environnement et la mise au point de techniques de construction adaptées aux conditions climatiques hivernales de l'Arctique.

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